SALVINIA MINIMA AND *S. OBLONGIFOLIA* (SALVINIACEAE) NEW TO CALIFORNIA, WITH NOTES ON THE *S. AURICULATA* COMPLEX

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ABSTRACT

Salvinia minima and *S. oblongifolia* are reported for the first time for California. These nonnative free-floating aquatic ferns likely escaped from residential or commercial ornamental ponds, water-gardens, aquaria or other cultivated sources. *Salvinia minima* is established in southern California, but *S. oblongifolia* is likely a non-persistent waif. We review the taxonomy of the "*Salvinia auriculata* complex" and re-examine previous determinations of sterile specimens using leaf venation characteristics in order to confirm the presence of *S. molesta* in California. We also provide a key to the identification of *Salvinia* species known or expected to occur in the State, and summarize the current naturalized status, habitats occupied, and regions where each species might become invasive.

KEY WORDS: aquatic plants, *Salvinia minima*, *Salvinia molesta*, *Salvinia oblongifolia*, nonnative plants, wetlands, wildland-urban interface

RESUMEN

Salvinia mínima y *S. oblongifolia* se reportan por primera vez en California. Estos helechos acuáticos de libre flotación no nativos posiblemente se dispersaron de estanques ornamentales, jardines acuáticos, acuarios o alguna otra fuente de cultivo. La *Salvinia minima* se estableció en el Sur de California pero la *S. oblongifolia* es posiblemente una planta abandonada no persistente. También revisamos la taxonomía del "complejo de *Salvinia auriculata*" y reexaminaremos las determinaciones previas de especimenes estériles utilizando las características de las venas de las hojas para confirmar la presencia de *S. molesta* en California. También proporcionaremos una clave para la identificación de las especies conocidas de *Salvinia*, así como de aquellas que se espera que se pudieran dar en el estado de California y resumiremos el estado actual de naturalización, los hábitats que ocupan y las regiones en las cuales cada especie se podría convertir en invasiva.

INTRODUCTION

Species of *Salvinia* are often difficult to identify, have a long history of use in cultivation, are known to escape and colonize indigenous wetlands, and often become invasive in new and remote regions around the world (Mitchell & Thomas 1972; de la Sota 1976; Forno 1983; Jacono & Pitman 2001). In this paper, we provide the first documented records of *Salvinia minima* Baker and *Salvinia oblongifolia* Mart. for California, and review their range, ecology, reproduction, potentially invasive behavior, mode of introduction, and likely pathways of dispersal.

Salvinia molesta D.S. Mitch. (giant salvinia or kariba-weed) has been reported previously for California (Hrusa et al. 2002; DiTomaso & Healy 2003; Riefner & Boyd 2005; Riefner & Boyd 2007). It is one of four morphologically similar species frequently referred to as the "*Salvinia auriculata* complex" (i.e., *S. auriculata* Aubl., *S. herzogii* de la Sota, *S. biloba* Raddi, and *S. molesta*), which are often difficult to separate when plants are infertile (Mitchell & Thomas 1972). To our knowledge, fertile *S. molesta* plants have not been documented growing outside of cultivation in California, making previous determinations problematic. We have determined and annotated sterile herbarium specimens of *S. molesta* by examining leaf primary venation patterns and comparing them with the illustrations depicted by Forno (1983). As a result, we confirm the presence of *S. molesta* in California, but cannot positively exclude other species in the *S. auriculata* complex. We also provide a key to the identification of *Salvinia* species known or expected to occur in the State, review the current naturalized status of urban and wildland habitats occupied by *Salvinia* species, and speculate on potential regions in California where each species might become invasive.

Salvinia minima (water spangles, common salvinia) and *S. oblongifolia* (giant water velvet) have not been reported previously from California in treatments of the Salviniaceae that address nonnative species growing outside of cultivation (Hickman 1993; Nauman 1993; Bossard et al. 2000; Hrusa et al. 2002; DiTomaso & Healy 2003; Roberts et al. 2004; Rebman & Simpson 2006; Bossard & Randall 2007; Clarke et al. 2007; DiTomaso & Healy 2007; Riefner & Boyd 2007; Dean et al. 2008; Roberts 2008; Jepson Flora Project 2009; USDA 2009a).

Salvinia minima

Salvinia minima is a floating aquatic fern widely recognized as an invasive species in the southern United States (Madeira et al. 2003; ISSG 2006; USDA 2009a). Like many aquatic plants, the natural range of *S. minima* is difficult to determine because it is grown in greenhouses and botanical gardens, and used in the water-garden industry and the aquarium trade, where it frequently escapes cultivation (de la Sota 1976; Tryon & Tryon 1982). *Salvinia minima* is native to Florida and Georgia in the southeastern United States, southern and eastern Mexico, Bermuda, the Greater and Lesser Antilles, Central America, and South America from Venezuela to northern Argentina (Mickel & Smith 2004). Tryon & Tryon (1982) and DiTomaso & Healy (2003) also report *S. minima* as native to the southern United States or Florida. Others, however, believe it has been introduced to Florida and elsewhere in North America (Weatherby 1937; Crow & Hellquist 2000; Jacono et al. 2001; Morgan 2009). The potential native occurrence of water-lettuce (*Pistia stratiotes* L.) in Florida has also stimulated a similar debate (Schmitz et al. 1988).

In the United States, *S. minima* is now established outside of cultivation in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, South Carolina, Texas, and Puerto Rico (Jacono et al. 2001; Jacono 2003; Morgan 2009). The USDA (2009a) maps these and other occurrences, including New Mexico and several mid-Atlantic and northeastern states. In New Mexico, *S. minima* is believed to be a non-persistent waif, and reports from Maryland, Massachusetts, New York, and Oklahoma have not been verified (Morgan 2009). A report from Minnesota also has not been confirmed (Nauman 1993).

Salvinia minima grows on still or stagnant waters of lakes and ponds, canals, slow-moving streams, ditches, shallow backwaters of bayous, oxbows, cypress swamps, marshes, and on mud (Lellinger 1985; Nauman 1993; Jacono et al. 2001). Much like *S. molesta*, the distribution of *S. minima* is, in part, limited by its low tolerance to freezing temperatures and saline waters (Jacono et al. 2001; Jacono 2003; Morgan 2009).

Salvinia minima is believed to be functionally sterile and like *S. molesta*, reproduces by continuous branching and fragmentation of rhizomes that generate large numbers of vegetative daughter plants (Schneller 1980; Jacono et al. 2001; Morgan 2009). Nauman (1993) recorded three apparently fertile specimens, all from Florida, and we have documented plants having a fertile axis growing in coastal San Diego County. Jacono (2003) reported that sporocarps are common on large plants in the southeastern United States.

Salvinia minima can reproduce at remarkably high rates and completely cover the surface of waterways if optimum growing conditions are present (Jacono et al. 2001; Jacono 2003; ISSG 2006). In the southern United States, particularly in Louisiana and Mississippi, *S. minima* is known to be a troublesome and invasive aquatic weed (Jacono et al. 2001). Dense infestations can block sunlight, decrease oxygen concentration to the detriment of other aquatic species, replace native plants that provide food and habitat for wildlife, clog irrigation systems, and block water intake screens and pipes of power plant facilities (Madeira et al. 2003; ISSG 2006). *Salvinia minima*, however, is prohibited only in Louisiana and Texas, and has not been included on the Federal Noxious Weed List or the State of California list of pest plants (Plant Protection & Quarantine 2002; California Department of Food & Agriculture 2008; Morgan 2009).

In southern California, *S. minima* is established at the wildland-urban interface (WUI) where it grows on mud, in algal mats, and shallow waters of urban drainages, and in stagnant backwaters of native wetlands. Because some plants in southern California are relatively small, likely owing to hydrological factors associated with urbanized watersheds (i.e., frequent flooding, fluctuations in water levels, and poor water quality), *S.*

minima could superficially resemble small patches of *Lemna* and therefore may be easily overlooked in the field (Fig. 1). Accordingly, *S. minima* may be more widespread in California than our records indicate.

Salvinia minima can overwinter in southern California stream environments or perennial wetlands when fragments of rhizomes are dispersed, get tangled in debris racks, and/or are sheltered among stems or roots of wetland plants, and then lie dormant until the return of favorable growing conditions in summer. Along Alberhill Creek, western Riverside County, *S. minima* grows in a large slough infested with *Eichhornia crassipes* (Mart.) Solms-Laubach (water hyacinth). In this population, discovered in February, 2009, most *Salvinia* plants show conspicuous symptoms of leaf dieback, and the pattern of browning is due presumably to cold-stress embolism. However, at this site *Salvinia* plants also produce new leaf growth and daughter plants at or just below the water surface, which apparently indicates its tolerance to cool winter temperatures. In the mild Mediterranean climate of Oceanside, in coastal San Diego County, the *S. minima* population discovered in April, 2009, overwinters without obvious cold-stress damage. At this site, and based on initial observations, *S. minima* can compete with but apparently cannot overgrow *Lemna* in stagnant waters of a culvert outflow basin (Fig. 2).

Accordingly, the ability of *Salvinia minima* to survive periods of reduced moisture or cool temperatures, and its potential for rapid vegetative reproduction have contributed to its ongoing invasive spread across the southern United States (Jacono 2003). *Salvinia minima* may not become a nuisance when growing in urban streams, but it could become invasive in sloughs, backwaters, ponds, and irrigation canals in California's mild Mediterranean coastal zones, possibly San Diego County, and the Lower Colorado River watershed in the Sonoran Desert region.

Salvinia minima is easily separated from other species of *Salvinia*, including species of the *S. auriculata* complex or *S. oblongifolia*, and other small floating aquatic plants using morphological features. *Salvinia minima* produces hairs on top of papillae that divide into four thin, spreading branches that remain free at the tips. *Salvinia minima* and *S. molesta* co-occur in drainages throughout the southeastern United States (Jacono 2003). In Brazil, *S. minima* can grow mixed with species of the *S. auriculata* complex (Forno 1983). Flooding, local environmental conditions, seasonal growth patterns, herbivory, and competition for space and nutrients with other floating plants may affect the local abundance of *S. minima* (Dickinson & Miller 1998). As a result, variable growth responses to environmental conditions and micro-habitat preferences in California could make detection of *S. minima* difficult in the field. In the Lower Colorado River, few *Salvinia* voucher specimens have been collected, and confusion between *S. minima* and small forms of *S. molesta* may be problematic (WAPMS News 1999). Therefore, small *Salvinia* plants growing with *S. molesta* populations or rafting with *Azolla* and *Lemna* should be examined carefully in order to avoid misidentifications.

As noted by Forno (1983) and Nauman (1993), botanists should make every effort to locate and collect fertile material to avoid misidentifications of sterile plants. In San Diego County, the fertile branches of *S. minima* plants bearing sporangia appear to be more-or-less subumbellate, i.e., originating at or near a common point on the axis, or divaricately branched (Fig. 3). However, the arrangement of the sporangia in the California specimens conflicts with the illustration of the fertile axis—elongate with the sporangia pinnately and alternately arranged—depicted by de la Sota and Jankowski (1996). The California material is somewhat similar to the fertile axis shown in the photograph of southeastern plants provided by Jacono (2003), but less elongate. Forno (1983) illustrated similar variation (short and long forms) of the fertile axes in *S. auriculata* and *S. herzogii*, and this may be an indication that minor variations of the fertile axis are not unusual in *Salvinia*. Accordingly, additional study and documentation is needed to accurately characterize the *S. minima* populations growing in California.

Specimens examined: **U.S.A. CALIFORNIA. Orange Co.:** City of Laguna Beach, vicinity of West St. and Pacific Coast Highway, UTM (NAD 83) 11S 0430540E 3707490N, elev. 4 m, growing in algae and shallow waters of a culvert outflow basin, 9 Jul 2008, *Riefner 08-219* (RSA, UC), same locality, 22 Oct 2008, *Riefner 08-307* (RSA). **Riverside Co.:** Cathedral City, Perez Rd. at Date Palm Dr., urban creek tributary to the Whitewater River, UTM (NAD 83) 11S 0550217E 3737981N, elev. ca. 82 m, uncommon but widely scattered, growing in algae, on mud, and in slow-moving waters, 5 Jul 2008, *Riefner 08-214* (RSA, UC); City of Lake Elsinore, S side of Alberhill Creek, W of Hwy. 74, along Baker St. vicinity of Bromley Ave. at Bennett St., UTM (NAD 83) 11S 0467394E 3728133N, elev. ca. 380 m, uncommon

Fig. 1. *Salvinia minima* plants in urban drainages may remain small owing to frequent flooding and poor water quality. These *Lemna*-sized plants may easily be overlooked in the field when growing in algae and on mud. Photograph taken in July, 2008, at Cathedral City, Riverside County, California.

but scattered in large slough infested with *Eichhornia crassipes*, 25 Feb 2009, *Riefner 09-17* (RSA, UC). **San Diego Co.:** City of Oceanside, North Santa Fe Ave. at Mesa Dr., UTM (NAD 83) 11S 0474261E 3678151N, elev. ca. 32 m, common but not invasive (fertile plants uncommon), growing with *Lemna* and *Wolffia* in culvert outflow basin, 9 Apr 2009, *Riefner 09-26* (RSA, UC).

Salvinia oblongifolia

Salvinia oblongifolia is native to Brazil where it can form dense, nearly pure colonies in lagoon habitats; occasionally, it can also grow mixed with species of the *S. auriculata* complex (de la Sota 1962; Richerson & Jacono 2005; Forno 1983). *Salvinia oblongifolia* is also grown for the horticultural industry, but is not known to grow in natural environments outside of cultivation in the United States (Kartesz & Meacham 2005; Richerson & Jacono 2005). Sexual reproduction is expected in *S. oblongifolia*, but it also reproduces primarily by vegetative propagation (Richerson & Jacono 2005).

Salvinia oblongifolia is a distinctive aquatic fern, and generally is easily identified (Fig. 4). *Salvinia oblongifolia* has somewhat rectangular floating leaves approximately three times as long as wide and short blunt papillae arranged in double rows on the upper leaf surface (Tryon & Tyron 1982; Richerson & Jacono 2005). Based on field observations, its prominent lower leaf keel and spongy aerenchyma tissue provide extra buoyancy and, like *S. molesta*, may increase its ability to compete for space on crowded waters by over-topping small floating plants and leaf debris.

In cultivation, *S. oblongifolia* is difficult to grow when temperatures drop below 50°F and its growth may also be impacted by fluctuations in pH (Jacono & Pitman 2001; Richerson & Jacono 2005). Accordingly, *S. oblongifolia* may not successfully overwinter in southern California. Although summer vegetative reproduction was observed in the Bixby Slough population, its presence may represent a non-persistent waif accidentally dispersed from cultivated sources to wildland habitats. *Salvinia oblongifolia*, however, could naturalize in

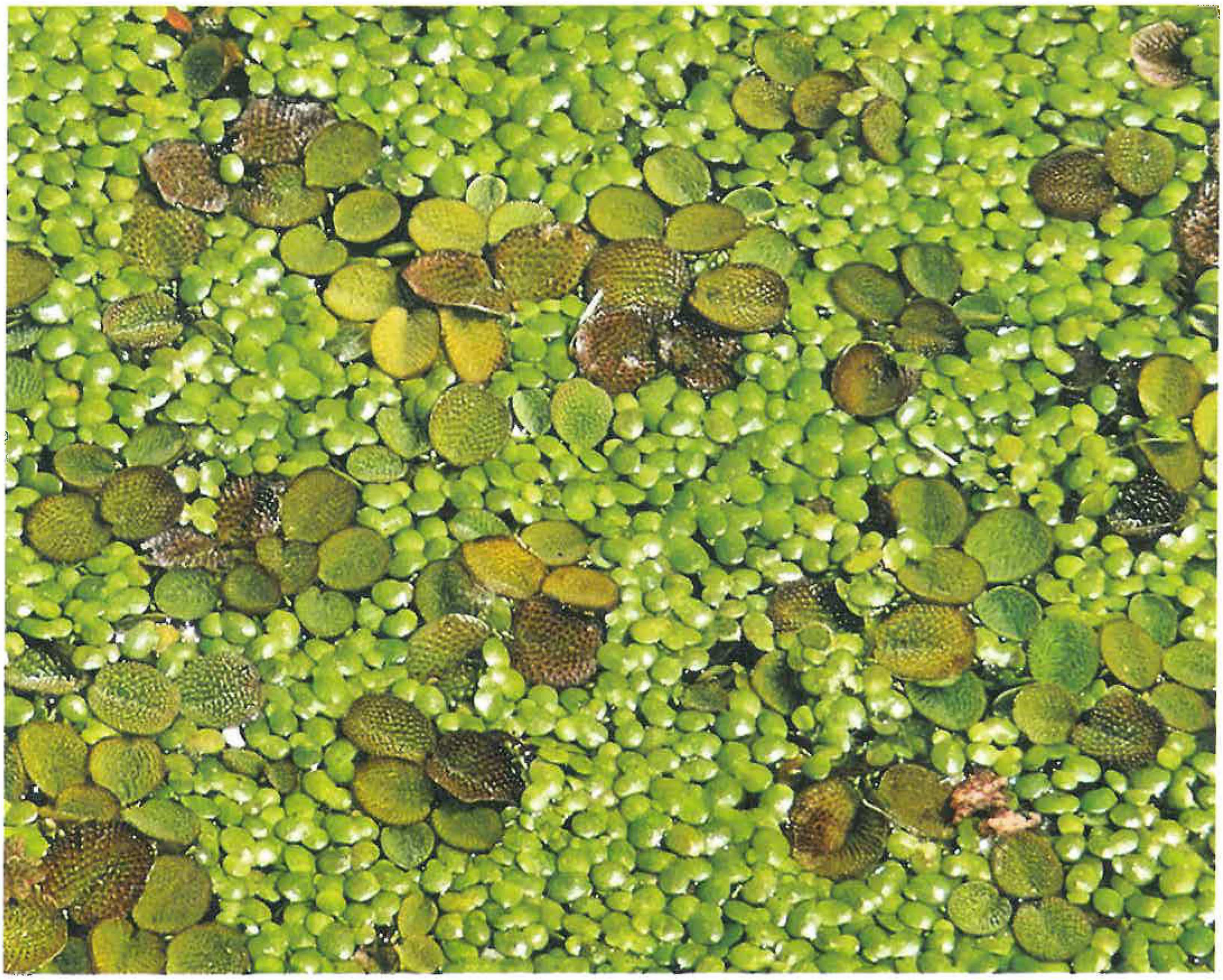

Fig. 2. *Salvinia minima* plants overwintering in a sheltered basin, coastal San Diego County. Some leaves are rusty brown, the coloration typically associated with maturity and senescence, but the plants do not exhibit symptoms of cold-stress embolism seen in a population discovered in the cooler, inland region of western Riverside County. Many of the older, larger *Salvinia* plants shown in this photograph are fertile. Photograph taken in April, 2009, City of Oceanside, San Diego County, California.

subtropical and tropical climate zones elsewhere in the southern United States, especially Florida (Jacono & Pitman 2001; Richerson & Jacono 2005).

Specimen examined: **U.S.A. CALIFORNIA. Los Angeles Co.:** Harbor City, Bixby Slough, vicinity of Dodge St. at 255th St., UTM (NAD 83) 11S 0380730E 3740064N, elev. ca. 11 m, uncommon, floating with *Lemna* sp. and *Ludwigia peploides* subsp. *montevidensis* in sluggish waters and clustered among emergent roots along bank of riparian woodland, 28 Jul 2008, *Riefner 08-251* (RSA, UC).

The Salvinia auriculata complex

Species of the *S. auriculata* complex share the defining character of "egg-beater" hairs (four hairs that join at the tip), which grow from the top of papillae on the upper surface of floating leaves (Mitchell & Thomas 1972). The floating leaves of all four species are orbicular to ovate, but vary widely in size according to environmental conditions and growth stage. Therefore, species of the *S. auriculata* complex are difficult to separate when fertile plants bearing sporocarps are absent (Tryon & Tryon 1982; Forno 1983; DiTomaso & Healy 2003; Mickel & Smith 2004).

Sporocarp-bearing plants are uncommon in the southern United States, and to our knowledge, fertile *S. molesta* has not been documented by herbarium specimens or reported in the literature for California (Hrusa et al. 2002; DiTomaso & Healy 2003; Riefner & Boyd 2005; Riefner & Boyd 2007). In Brazil, more than one species of the *S. auriculata* complex can grow together in the wild (Forno 1983). We cannot, therefore,

Fig. 3. Pressed and dried fertile *S. minima* plants collected from a culvert basin in Oceanside, San Diego County, showing sporangia born on a more-or-less subumbellate or a divaricately branched axis. The arrangement of the sporangia in the California specimens differs from the elongate, pinnately and alternately arranged sporangia illustrated by de la Sota and Jankowski (1996).

completely rule out the possibility that other species of the *S. auriculata* complex could occur in California. Accordingly, representative sterile herbarium specimens previously determined as *S. molesta* or identified as the *S. auriculata* complex representing a wide range of growth forms were selected for study using illustrations of leaf venation patterns and the methodology outlined by Forno (1983), which follows:

Methodology: Dried and pressed leaves were placed in boiling water with a few drops of household detergent for a few minutes and allowed to cool. The leaves were then scraped of surface hairs and cleared using a 5% NaOH solution (adapted here using 20% Clorox solution) to aid viewing the leaf venation patterns under a dissecting microscope. The venation pattern of each specimen was then compared to the species-specific illustrations depicted in Forno (1983). (Clearings made by A. Smith and H. Driscoll, with permanent slide mounts archived at UC.) Cleared leaves of specimens cited by CCH (2009) and deposited at CDA (Herbarium of California Department of Food and Agriculture) include: Imperial Co. (*Cason & Mizumoto s.n.*, *Herod & Pilman s.n.*), Mendocino Co. (*Harrie s.n.*), Riverside Co. (*O'Connell s.n.*), San Diego Co. (*Riveria s.n.*, *Stevens s.n.*), and San Luis Obispo Co. (*Knowles s.n.*, *Stoltz s.n.*).

As a result of this study, we confirm the presence of *S. molesta* in California, but cannot positively exclude *S. biloba*, which has somewhat similar venation. However, *S. auriculata*, which is morphologically similar to *S. molesta*, is the other species of the *S. auriculata* complex most likely to occur in southern California.

FIG. 4. *Salvinia oblongifolia* has somewhat rectangular leaves approximately three times as long as wide and short blunt papillae that are arranged in double rows on the upper leaf surface, which make for easy identification. A prominent lower leaf keel and spongy aerenchyma tissue provide extra buoyancy that may increase its ability to overtop small floating plants, leaves, and roots, and compete for space on crowded surface waters. Photograph taken in July, 2008, at Bixby Slough, Harbor City, Los Angeles County, California.

Salvinia molesta

Salvinia molesta is well known for its phenomenal growth rate and worldwide invasive spread, and is therefore widely regarded as one of the world's worst aquatic weeds (Holm et al. 1977; Thomas & Room 1986; Jacono & Pitman 2001). In the course of just a few decades, *S. molesta* spread from its native Brazil to aquatic habitats in many tropical and subtropical regions around the world, including the southern United States and northern Mexico (Jacono & Pitman 2001; McFarland et al. 2004; LCR 2009). It may be expected to co-occur wherever *Eichhornia crassipes* is established (McFarland et al. 2004), although *Salvinia* species appear to be more cold-sensitive.

Even the name of this *Salvinia* has been a source of contention. De la Sota (1995) replaced *S. molesta* with *S. adnata* Desv., an older name. However, because the Desvaux type is sterile and cannot be positively identified with confidence, and is also of uncertain provenance, the use of *S. adnata* should be considered a "name of uncertain application" (Moran & Smith 1999). Most authors have continued to use the name *S. molesta*, as recommended by Moran and Smith (1999).

In the United States, *S. molesta* was first documented in 1995 growing outside of cultivation in South Carolina; by 1999, the first collections from California were made from the Imperial National Wildlife Refuge, Imperial Co., from near Blythe, Riverside Co., in the Lower Colorado River drainage, from a pond near Fallbrook, San Diego Co., and from the San Diego River floodplain (without voucher), also in San Diego Co., southwestern California (Jacono & Pitman 2001; Hrusa et al. 2002). It has since been documented from

canals near El Centro and Holtville in Imperial County, and from man-made ponds and native wetland habitats from coastal San Diego and Orange counties north to Fort Bragg, Mendocino County, in coastal northern California (CCH 2009). *Salvinia molesta* has been reported recently from Humboldt County, which is also in coastal northern California (Calflora 2009). Accordingly, the distribution of *S. molesta* in California is more widespread than previously mapped by McFarland et al. (2004) and Jacono & Richerson (2005).

Though benign within its native range, *S. molesta* is an aggressive aquatic menace that can suppress growth of native vegetation, degrade water quality and fish and wildlife habitats, clog irrigation canals, interfere with recreational activities and utilization of water resources, and impact numerous other wetland values and functions. *Salvinia molesta* and other species of the *S. auriculata* complex are included on the Federal Noxious Weed List, and therefore prohibited from importation to the United States and from transport across state lines (Plant Protection & Quarantine 2002). Although species of the *S. auriculata* complex are included on the State of California weed list ("A List") of pest plants, *S. molesta* has become an invasive pest in several national wildlife refuges located along the Lower Colorado River (California Department of Food & Agriculture 2008; LCR 2009). *Salvinia molesta* has also been identified as a "High Alert" plant by the California Invasive Plant Council (Bossard et al. 2006).

Salvinia molesta is distinguished from other species in the S. *auriculata* complex by the arrangement of the fertile axis, which bears a large number of sessile sporangia arranged in a dorsiventrally arranged cyme (Forno 1983). Sporocarps are small, ovoid, apiculate, and contain a high number of empty sporangia or abortive spores (Mitchell & Thomas 1972; Tyron & Tyron 1982). However, no fertile material of any *Salvinia* in California has been collected.

The leaf venation pattern of *S. molesta* was used by Forno (1983) to distinguish it from other members of the *S. auriculata* complex; however, this pattern is somewhat similar to that found in *S. biloba*. These two species can be carefully separated by examining the number and shape of the primary areoles situated between the keel and the margin of a tertiary leaf; i.e., 5 to 10 areoles in *S. molesta*, and 8 to 12 areoles in *S. biloba*, with the latter generally having 10 or more present. Because of the similarity of leaf size, shape, and patterns of venation, populations of *S. molesta* in California and Arizona should be carefully examined for the presence of fertile plants to ensure that *S. biloba* is not present in California. *Salvinia auriculata*, possibly to be expected in California, greatly resembles and can be confused with *S. molesta*. The leaf venation of *S. auriculata* is reticulate and similar to the venation of the outer third of a *S. biloba* leaf. Illustrations of the primary leaf venation patterns of *S. auriculata*, *S. biloba*, and *S. molesta*, and photographs of sporocarp-bearing plants are depicted in Forno (1983).

Salvinia auriculata has been reported previously from Mexico and Puerto Rico, but not from California (Mickel & Smith 2004; USDA 2009c). Therefore, *S. auriculata* is included in the following key that will serve to identify the sterile species of *Salvinia* known or expected to occur in California.

A KEY TO STERILE MATERIAL OF SPECIES OF *SALVINIA* IN CALIFORNIA (ADAPTED, IN PART, FROM FORNO 1983)

1. Floating leaf blades oblong, generally 2–3 times longer than wide; papillae (stalks) supporting hairs on upper blade surfaces < 0.1 mm long _____ **S. oblongifolia**

1. Floating leaf blades round, or if slightly oblong (suborbicular), less than 1.5 times longer than wide; papillae supporting hairs on upper blade surfaces of well developed leaves to 1 mm long.
   2. Hairs on tips of papillae of upper surface of floating leaves free at tips; leaf blades generally 0.5—1.0 (–1.5) cm long _____ **S. minima**
   2. Hairs on tips of papillae of upper surface of floating leaves joined into a darkened knot at tips ("egg-beater hairs"); leaf blades generally 1.5—2.5 cm long.
      3. Leaf venation of ± isodiametric or slightly elongate areoles (length to ca. 2 times width) in marginal 2/3 of leaf lobe; main axis of submerged leaves (root-like organs) with short, recurved branches distally; not known from CA, to be expected _____ **S. auriculata**
      3. Leaf venation of areoles of unequal length (the outer much shorter than the inner) in marginal 2/3 of leaf lobe; main axis of submerged leaves (root-like organs) with distal branches not recurved; widespread in coastal and southern CA _____ **S. molesta**

TABLE 1. Summary of distributional records, current naturalized status and occupied habitats, and potential invasive behavior of *Salvinia* species known or expected to occur in California.

Species	Significance in California	Naturalized Status and Habitats	Potential Invasive Behavior
Salvinia auriculata	Not currently known, but expected in southern counties	NCI	Possibly Sonoran Desert region
Salvinia minima	New to State; expected elsewhere in southern California	N – urban creeks NW – slough	Possibly coastal southern California, especially San Diego Co., and Sonoran Desert region
Salvinia molesta	Identification of infertile *S. molesta* confirmed. Similar species in the *S. auriculata* complex cannot be excluded	N – backyard ponds, agricultural ponds, drains, and canals NW – river channels, backwaters, and floodplain ponds	Sonoran Desert region, central and southern coastal regions, especially San Diego Co., but unlikely elsewhere
Salvinia oblongifolia	New to State; first record growing outside of cultivation in U.S.	C – slough	Unlikely in California

DISCUSSION

Urbanization in arid and semiarid regions often brings unintended changes to fluvial ecosystem processes and threats to native biodiversity, including replacement of ephemeral washes with year-round waters and the introduction of new exotic species (Schwartz et al. 2006; White & Greer 2006; Roach et al. 2008). Seasonal stream flows and summer-dry conditions of southern California's arid climate have in the past acted as a barrier to establishment by many nonnative plants dispersed at the WUI (Brigham 2007). The availability of year-round sources of water, however, generated by man-made activities has inadvertently created numerous new wetland and riparian habitats that have significantly increased the likelihood that nonnative facultative wetland plants escaping cultivation could migrate from benign urban environments outward along the WUI to establish in native wetland habitats (Riefner & Columbus 2008).

In addition to intentional introductions for water-gardens, federally listed noxious plants, including *S. molesta*, have also been inadvertently introduced as contaminants with non-invasive wetland plants sold over the internet (Kay & Hoyle 2001; Maki & Galotowitsch 2003). The continuing growth of internet sales and demand for the water-garden industry will increase the likelihood that species of *Salvinia* will continue to be introduced by cultivation and escape to California's urban and wildland wetland habitats.

As a result of field experiences in southern California and a review of pertinent literature, the new distributional records reported here, current urban and wildland habitats occupied by *Salvinia* species, and potential regions where *Salvinia* species might become invasive are summarized in Table 1. Naturalization categories shown in Table 1, which are somewhat subjective, follow Hrusa et al. (2002) in order to allow consistency in data compilation of new introductions, which include: naturalized in wildlands (NW); naturalized outside of wildlands, including WUI habitats (N); casual or waif populations (C); and no current information (NCI).

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